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INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

June 1976
NSRP 0002

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Proceedings of the REAPS Technical Symposium

Paper No. 13: Automation and Productivity in Discrete Part Manufacturing

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 1976	**N/A**	**-**

4. TITLE AND SUBTITLE	
The National Shipbuilding Research Program: Proceedings of the REAPS Technical Symposium Paper No. 13: Automation and Productivity in Discrete Part Manufacturing	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192, Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**17**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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Proceedings of the REAPS Technical Symposium

June 15-16, 1976

Atlanta, Georgia

Research and
Engineering for
Automation and
Productivity in
Shipbuilding

IIT RESEARCH INSTITUTE
10 WEST 35 STREET
CHICAGO, ILLINOIS 60616

AUTOMATION AND PRODUCTIVITY
IN
DISCRETE PART MANUFACTURING

John M. Evans, Jr.

National Bureau of Standards

Washington, D.C.

Dr. Evans joined the National Bureau of Standards in September 1970 as a program analyst in the Office of the Director of the NBS. He transferred to the Institute for Computer Sciences and Technology of NBS in 1972 and became Deputy Manager of the Office of Developmental Automation and Control Technology when it was formed in 1973. In that capacity he manages the development of guidelines and standards for computer aided design and manufacturing systems to benefit both government and industry.

He received his B.A. degree in Physics from Yale University in 1964 and his Ph.D. in Physics from the University of Colorado in 1970.

The subject of this conference is automation and productivity in shipbuilding. I am going to talk about automation and productivity in the general context of discrete part batch manufacturing, which includes shipbuilding, to try to provide a wider prospective on the technical strategies that are being used in applying automation in manufacturing, their impact on productivity enhancement, and the wider economic implications of enhancing productivity.

My program at the National Bureau of Standards is the Automation Technology Program. Our program is designed to assist other Government agencies in applying computer-based automation systems to meet their mission objectives and to develop standards, guidelines, and performance measures which will assist Government and industry to effectively use automation systems to improve productivity and improve job safety. It is from this perspective that I would like to speak to you this morning.

Productivity

The primary motivation for using automation in manufacturing is to increase productivity. Why is productivity important? There are three basic reasons why productivity is important to the economic health of the United

States that have been emphasized by the National Productivity Center, the Department of Commerce, and the General Accounting Office.

First is international trade. We are running out of basic materials, and find ourselves in an increasingly competitive marketplace to obtain the raw materials we need in our economy. Of course, petroleum is the obvious example of our increasing dependence on other countries, but there are many other materials for which we are even more dependent on foreign sources. For example, we import 100% of the chromium, cobalt, manganese, and tin that we use. In return for these raw materials, we basically trade agricultural goods and products from our discrete part batch manufacturing industries. For this reason, the efficiency of those industries is of crucial interest to the well being of the country, as reported by the Comptroller General of the United States in a recent report to Congress.

The second reason that productivity is important is inflation. The Secretary of Commerce has gi ven testimony to Congress, pointing out that productivity is the only source of real increases of wealth in the economy. Price increases not resulting from true increases of output are simply inflationary. In fact, the negative correlation between price increases and productivity increases, on an industry by industry basis, is very strong. Data developed by the Bureau of Labor Statistics and published by the National Commission on Productivity (now the National Productivity Center) shows clearly that those industries with higher increases in productivity tend to have lower increases in prices, and those industries with low increases in productivity tend to have higher yearly price increases.

The third reason that productivity is important is that productivity is the basic source of increased real consumable wealth. The correlation between real compensation per man hour, that is, wages after subtracting the effects of inflation, and output per man hour, that is productivity, is again very strong. Productivity increases result in real wage increases, and the labor unions recognize this, and generally support the concept of increasing productivity.

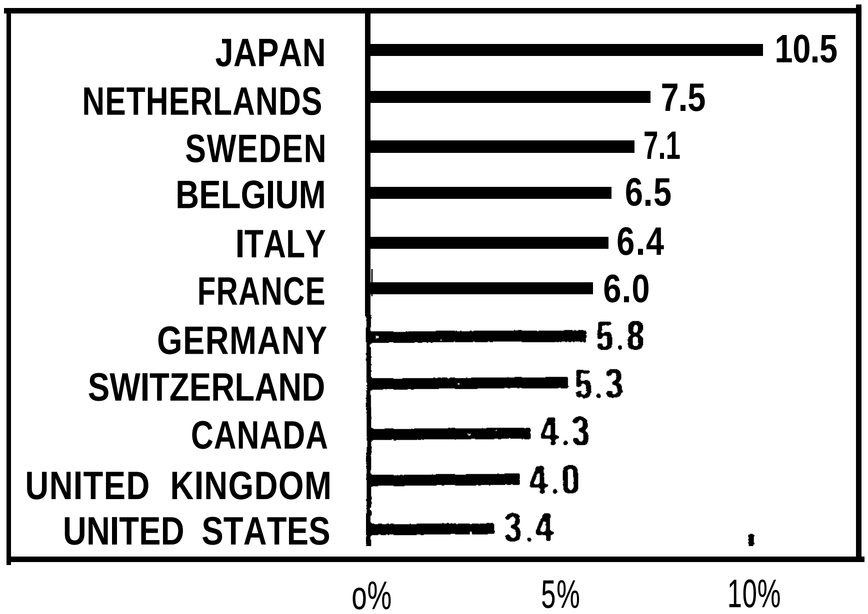
If productivity is thus so important., how are we doing? The answer is that we are not doing very well. When compared with the rate of productivity increases of all of our competitor nations in the free world, the United States has ranked the lowest in terms of increased productivity in recent years. Specifically, during the period between 1960 through 1973, the average annual increase in output per man hour in the United States was 3.4%. This should be compared with increases in Germany of 5.8%, France 6.0%, and Japan of 10.5%. The question that we must address is what we can do to improve our performance in increasing productivity. (See Figure 1.)

Productivity Increases Through Automation

Automation can significantly improve productivity in manufacturing. To consider the specific technologies of automation, we must distinguish between different types of manufacturing industries. All manufacturing industries may be divided basically into three classes, each with a distinct and identifiable process technology, that is, a distinctly different means of manufacturing their products.

PRODUCTIVITY GAINS

OUTPUT PER MAN-HOUR RATES OF CHANGE 1960-1973



SOURCE: U.S. DEPT. OF LABOR

FIGURE 1

Yearly average productivity increases for eleven countries, 1960-1973. The United States had the lowest rate of productivity increase during this time period among all of these competitor nations.

The continuous process industries, such as petroleum, chemicals, steel and other primary metals deal with a continuous flow of materials such as a flow of liquid **or** a continuous strip of paper. The continuous process industries account for some 47% of the value added in manufacturing. The remaining 53% of our manufacturing industries are discrete part industries in which the products are individual items such as airplanes or transistors.

Within discrete part manufacturing industries it is possible to distinguish between mass production, such as automobiles or consumer appliances, which use well known techniques of assembly line and transfer line production, and discrete part batch industries where products are made on general purpose machines in small lots or batches ranging from sizes of one to several hundred-thousand. These batch manufacturing industries account for 75% of the dollar value of discrete part manufacturing, $137 billion in value added in 1973, and the greatest potential for improving productivity through the application of the computer lies in these industries.

If you go out and visit typical discrete part batch manufacturing industries in the United States, you will find that the technology is virtually unchanged from that used in World War II. That is, we mostly cut metal parts on manual machine tools, we inspect those parts by hand, and we assemble them by hand.

Some 25 years ago a new technology appeared for discrete part batch manufacturing, based on the application of a computer to control the motions of a general purpose machine tool. This new machine tool is called a numerically controlled machine tool, **or NC** machine tool, because the motions of the tool are controlled by numbers on a paper tape or in the memory of a control computer. One can change the part being manufactured by simply changing the part program,

that is, the numbers on the tape or in the computer memory. NC machine tools typically increase productivity by a factor of 3 or more, that is 300%.

This experience of increasing productivity is borne out by our experience in our own instrument shops at NBS, where we have four NC machine tools and one NC inspection machine in operation. For example, we manufacture authorities. A full set of these weights made with NC machine tools cost **$700,** one third the cost of a set made with conventional tools. Again, a mirror mount is a typical low volume product made in our shops. When made with NC, a mirror mount costs $62. When made manually, it used to cost over $200. These figures are typical of industry experience with numerical control.

The application of exactly the same principles of computer control to manipulators for materials handling and assembly operations has resulted in this technology of industrial robots. That is, the motions of an industrial robot are controlled by numbers in the memory of a control computer.

The greatest gains of productivity come from integrating general purpose programmable machine tools with general purpose programmable materials handling systems to create integrated manufacturing systems. A typical example is the Fujitsu Fanuc factory in Japan where eight NC lathes and an industrial robot are all operated by a central computer in the production of stepping motors. Increases in productivity in such integrated manufacturing systems range up to 2000% and more.

Integrated Manufacturing Systems

This, then, is the primary point that I would like to emphasize: that the trend in discrete part batch manufacturing is toward integrated manufacturing systems, where computer controlled machines are integrated together with higher levels of computer control into highly automatic computer aided manufacturing systems.

Let's examine a few examples of the state of the art in integrated nianu-facturing systems around the world.

An example of an advanced integrated manufacturing system in the United States is the Kearney and Trecker Flexible Manufacturing System installed at an Allis Chalmers plant. In this system the operators get instructions from CRTs displaying instructions from the computer. Following those instructions, the operators set up the next work piece on pallets, which are loaded onto robot carts. The robot carts move the parts around the factory to the correct machine tool where they are registered, the pallets are automatically loaded into the machine tool, and the correct machining operations are carried out under computer control. At the end of the tool cycle, the part can be moved to another machine or can be returned to the set-up area to be unloaded.

The use of fixed pallets for holding parts has been dominant in the machinery industries in building integrated manufacturing systems.

The most advanced existing manufacturing system in the world is considered to be the Fritz Heckert plant in East Germany. Like the Kearney and Trecker system, this system consists of general purpose machine tools and inspection machines linked together by automatic materials handling systems. In this system, the pallets holding the work pieces are moved around on air bearing ways with linear induction motors, a concept that rivals some of the most advanced concepts in transportation systems at the current time.

The most advanced proposed concept in integrated manufacturing systems is the Japanese Methodologies for Unmanned Manufacturing Systems, or MUMS program. This program, which is funded by the Japanese Government at a level of $113 million, has as its goal the development of an automatic prototype unmanned factory for producing parts for machine tools. The concept is a series of machine tool cells linked together by a materials handling system. The materials handling system is in two levels, one level carrying palletized parts and the second level carrying palletized tools. Both the parts and the tools are to be loaded into the machine tools by computer controlled robot systems. The increases in productivity in this prototype plant are expected to be 7000 to 8000 percent.

The Japanese are also exploring the use of robots in automatic assembly. A recent Kawasaki film shows a research laboratory with ten robots of the Unimate type assembling small gasoline motors for, of course, Kawasaki motorcycles.

The ultimate goal in automation in integrated computer aided manufacturing systems is to link the higher level design and management processes together with the systems actually controlling the machine tools.

We can now create systems where a man can sit at a graphics terminal and design a part. The data base that is created in the computer describing that part can then be used to produce drawings on computer controlled drafting boards and to produce the computer programs or punched tapes for operating the machine tools. Eventually, design, process planning, and scheduling and control will a11 be integrated together with machine tool control systems in an overall integrated system.

The most ambitious concept of this type at the present is the Air Force Integrated Computer Aided Manufacturing Project. This program, which is approved by the Department of Defense at a level of $100 million, has as its goal advancing the generic technology for discrete part batch manufacturing, and demonstrating that technology in a specific area of sheet metal fabrication and assembly, obviously an area of fundamental interest to Air Force procurement.

Architecture of Computer Aided Manufacturing

The way in which the various modular components of computer aided manufacturing systems are linked together is a subject of great current debate, and, indeed, is the subject of the first phase of the Air Force ICAM program.

Every industry can tell you what a computer aided manufacturing system is. The problem is that each one has a different basic concept of what the modular components of that system are and how they are linked together. In addition, a further problem comes in considering the relationship of the host computer system to the applications programs that are the CAM system.

Recently, concepts of CAM have been based around the idea of a centralized data base, with its own data base manager, maintaining all of the data files for the various applications programs in an application independent format. This allows maximum flexibility in writing and integrating various CAM applications programs into an integrated system. However, fourth generation computer systems are likely to be highly distributed, with both distributed processors and distributed data bases. The question of interface standards that are required to integrate various modular components of CAM systems, both hardware and software, now becomes a crucial issue in the development and widespread implementation of CAM systems. It is this area that is of fundamental interest to our program at the National Bureau of Standards.

Summary

In conclusion, what we are talking about here is computer aided manufacturing: technology to increase productivity. With potential productivity gains of hundreds or even thousands of percents, why haven’t we done better in applying this technology?

The General Accounting Office has identified high costs and lack of understanding of the technology and its implications as the principle reasons for the slow diffusion of advanced manufacturing technology.

The National Bureau of Standards is attacking these problems by providing guidelines and case studies to help Government and industry understand the technology, and by developing the standards, the performance measures and the technology to reduce the costs of procuring and using NC and CAM technology.

1. The application of computers can improve productivity in discrete part batch manufacturing, including the shipbuilding industry, by up to thousands of percent.

2. The lowest levels of computer aided manufacturing consist of machine tools and computer controlled materials handling systems such as industrial robots.

3. A dominant technical strategy that is emerging in the automation of discrete part batch manufacturing is the integration of automated computer controlled materials handling systems with NC machine tools.

4. The greatest gains in productivity will come with the eventual integration of the higher level management functions and computer aided design with the computer systems actually controlling the machine tools and robot systems.

The fact that people are arguing about particular details of CAM systems is not nearly as important as the fact that there is a coherent technical strategy emerging in the field and that the economic payoff in existing applications is enormous.

The important thing for your industry, then, is not so much which particular system to buy, but, rather, to get started, to get on the learning curve, and to start reaping t gains in productivity that will help both your industry and the overall economy of the country.

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